

## DIFFERENCES IN INTENSITY OF SETTING OF OYSTERS AND STARFISH

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The ecological association of the American oyster, *Crassostrea virginica* Gmelin, and the common starfish, *Asterias forbesi* Desor, is well known. The latter, in many areas, is the chief enemy of the former. These common representatives of the two phyla are not only found living under the same conditions, but also resemble each other in their methods of reproduction. They are both diecious and oviparous, discharging eggs directly in the sea water where fertilization takes place. Spawning in both species occurs during the same season, although the starfish usually begin approximately two weeks earlier. The lengths of the spawning and setting seasons of both species are of approximately the same duration, the latter, in Long Island Sound, extending in some years from early July until the first week of October (Loosanoff, 1936; Galtsoff and Loosanoff, 1939; Loosanoff, 1937-1954).

A comparison of the reproduction of these two species could be carried even further because both produce a large number of eggs from which small planktonic larvae develop. After a relatively long pelagic period of two to three weeks, the larvae of both species descend to the bottom where they metamorphose into juvenile oysters or starfish. This step in the development of these organisms is usually known as setting and the recently metamorphosed individuals are called either starfish or oyster set.

Regardless of the similarity of the reproductive behavior of these two invertebrates, and even though their larvae develop during the same season and under the same general ecological conditions, such as temperature, salinity, pH, turbidity, currents, winds, etc., their intensity of setting in relation to each other shows a complete absence of any definite pattern. This conclusion is based on our observations of reproduction in these two species in Long Island Sound during the 18-year period extending from 1937 through 1954. Brief summaries of these observations, together with the analysis of the data on which we have based our conclusions, are presented in this article.

The method used in our studies consisted of counting, at regular intervals, the numbers of oyster and starfish sets found on the collectors. These collectors were wire-mesh bags filled with clean oyster shells. The bags were anchored on the bottom and buoyed in a special manner described by Loosanoff and Engle (1940). The collectors, all of uniform size and shape, and containing approximately the same number of shells, were placed at stations situated along the Connecticut shore of Long Island Sound in the area extending from the Bridgeport to the New Haven harbors, a distance of approximately 30 miles. The stations were established at

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10-, 20-, and 30-foot depths and their number in the different years varied from seven to 18. Since 1944, however, the number of stations has always been ten and their locations have remained the same.

At semi-weekly intervals the collectors were removed from the stations and brought in moist condition to the laboratory for examination. Using a low-power dissecting microscope the oyster set was counted on ten shells selected at random from each bag, and then the same ten shells, plus an additional ten shells, were examined for the presence of starfish set. The results were later expressed as the

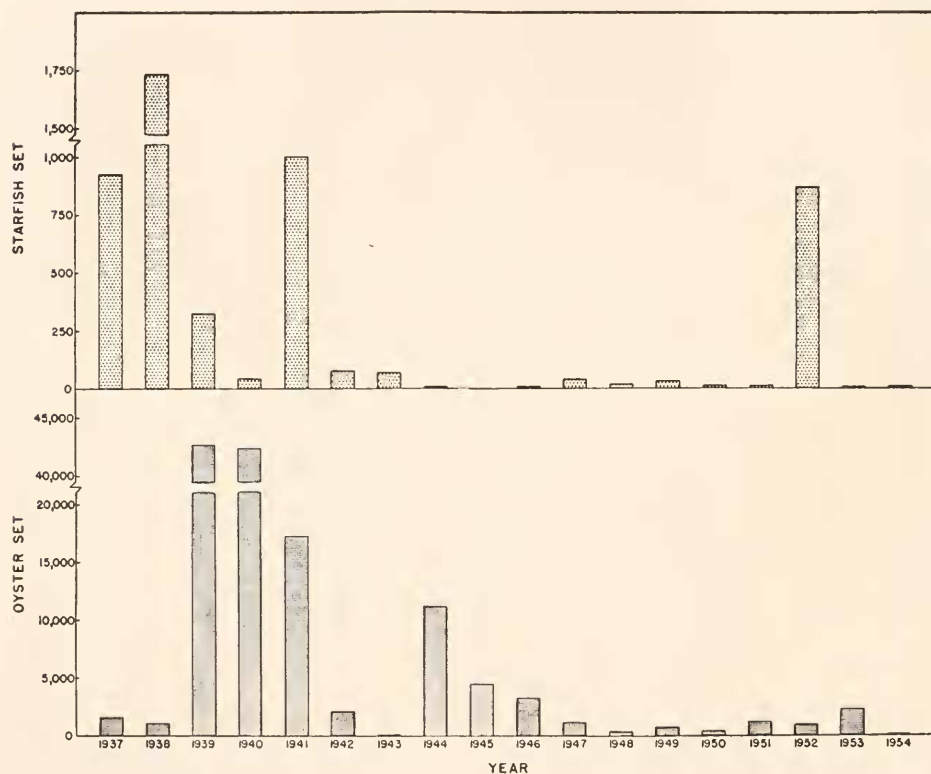


FIGURE 1. Average numbers of oyster and starfish sets per station recorded in different years on 100 shell-surfaces. Long Island Sound, 1937-1954.

number of set of each species per 100 shell-surfaces. Counting of set was done only on the clean inside surfaces of the shells.

Each time a bag was removed from the water it was immediately replaced by a new one with unused shells. To obtain more reliable data we used, as a rule, two bags at each station, and averaged the results. The period during which the observations were made usually extended from the beginning of July into October, covering, therefore, the entire setting season of both species.

The intensities of the oyster and starfish sets in the different years are shown in Figure 1. They are averages based on the number of set found during the entire

summer on the inside surfaces of 100 shells at each station. As can be seen, during the 18-year period the oyster set was usually heavier than that of the starfish. The only exception was 1938 when the average seasonal starfish set per station was 1731 per 100 shell-surfaces, as compared with 1090 for the oysters. The year of maximum starfish set for the entire period of our observations was also 1938, while the year of heaviest oyster set was 1939 when 42,623 spat per station was the season's average. As the other extreme, we may mention that in 1945 only one recently-set starfish was found on our collectors during the entire summer, while the lightest oyster set occurred in 1943 when the average seasonal set was only 72 spat per station per 100 shell-surfaces.

To study further the discrepancies in the setting of the two species, product-moment correlations between the oyster and starfish sets were computed with the set for each year expressed as a percentage of that of the year when the highest setting took place. Thus, 1939 was taken as the 100 per cent year for oysters, and 1938, for starfish. This approach gave a range for each variable of 0 to 100 per cent. In each case, however, the distribution was badly skewed with most of the years falling between 0 and 10 per cent.

To make the analysis more detailed, correlations were determined for the stations located at each of three depths and also for the combinations of stations at several depths.

All correlations obtained were very low:

For 10-foot stations only	$r = .06$
For 20-foot stations only	$r = -.05$
For 30-foot stations only	$r = .03$
For 10- and 20-foot stations	$r = -.02$
For 10-, 20-, and 30-foot stations	$r = -.01$

With  $N$ , number of years in this case, being 18, the product-moment correlation ( $r$ ) must be at least .47 to be significant at the .05 level. The low correlations obtained indicated that there was no definite relationship between the oyster and starfish sets. However, since the distribution of the data was badly skewed, we thought that the use of the conventional product-moment correlation coefficient might give somewhat misleading results. To verify the conclusions we decided to use rank-order correlations ( $r_s$ ) also. For this, the yearly setting data of each species were assigned ranks from 1 to 18, in order of magnitude, and the correlations were then computed according to the rank correlation coefficient formula. The coefficients obtained were as follows:

For 10-foot stations only	$r_s = .19$
For 20-foot stations only	$r_s = .03$
For 30-foot stations only	$r_s = .06$
For 10- and 20-foot stations	$r_s = .07$
For 10-, 20-, and 30-foot stations	$r_s = .02$

Since the value of the rank-order correlation coefficient necessary for significance at the .05 level, with  $N = 18$ , is .47, all correlations obtained were not significant.

The absence of correlation was also well illustrated by scatter plots of the oyster set against the starfish set. A plot showing the lack of relationship between

the rank-order of the set of the two species at the 10-, 20-, and 30-foot stations all combined in one group, is given in Figure 2. As may be seen from this plot, and from the low coefficients for each depth and combination of depths, almost complete dissociation is suggested between the variables. Therefore, we concluded that there is no appreciable relationship between the intensities of the starfish and oyster sets for the years and depth-stations for which data were available.

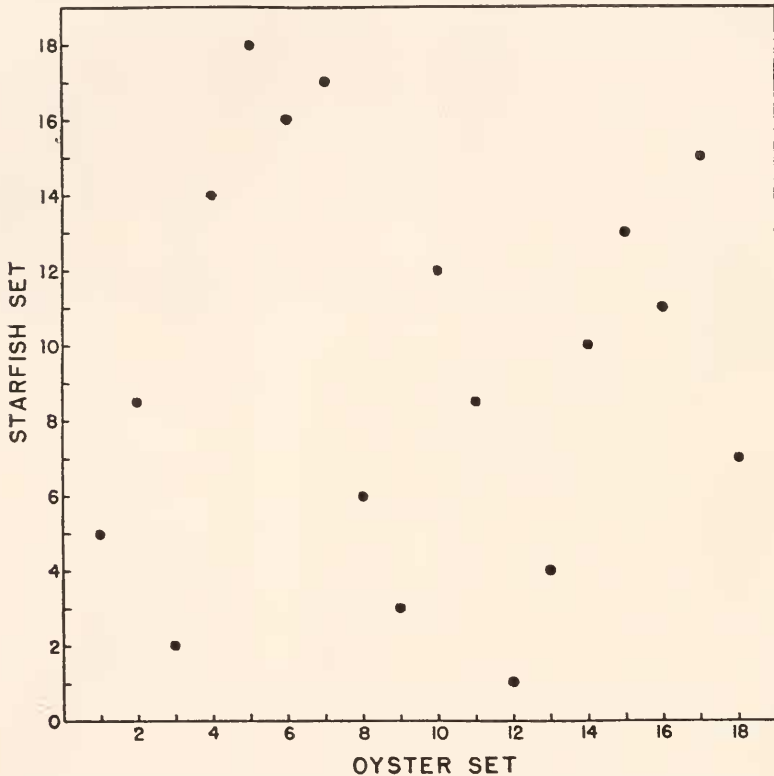


FIGURE 2. Rank-order relationship of oyster and starfish sets at 10-, 20-, and 30-foot stations. Long Island Sound, 1937-1954.

These studies, conducted for almost two decades, emphasize once more the danger of forming conclusions regarding the relationship between certain natural phenomena, if such conclusions are based on relatively short periods of observations. For example, if only the first four years of our period of observations were considered, a highly significant negative correlation between the intensity of the oyster and starfish setting would be indicated (Fig. 1). This, obviously, could lead to serious misconceptions. In our case, fortunately, by continuing the studies for many more years a much truer understanding of the situation was made possible.

The question naturally arises as to the causes responsible for the absence of a well-defined pattern in the intensity of setting of the two species in relation to each other. At present we are not prepared to discuss this question at length. Nevertheless, as mentioned above, we know that adult oysters and starfish live and propagate under the same ecological conditions, and that their larvae, which are present in the water during the same season, are subjected to the same general sets of environmental factors. We may suppose, therefore, that unfavorable conditions, such as relatively low summer temperature, strong winds, etc., would affect the larvae of both species more or less equally. Because oyster and starfish larvae are microscopic in size and both pelagic, we may also assume that most of the predators of one would also be feeding upon the other.

Low salinity, conversely, might be suspected as a factor which could unfavorably affect starfish larvae while leaving oyster larvae relatively unaffected. It is known that even adult starfish cannot survive in a salinity lower than 16.0 parts per thousand (Loosanoff, 1945), while oysters can normally live and reproduce in water of much lower salinity. However, in Long Island Sound proper, where our studies have been conducted, the salinity in summer is steadily near 27.0 parts per thousand, thus being within the optimum range for both starfish and oysters. Consequently, this ecological factor cannot be considered, under our conditions, as important in favoring one or the other species.

The density of the parent populations in different years is another factor to consider. Our observations on these populations (systematic surveys of the occurrence and distribution of starfish are made twice a year and oysters are collected near our stations at weekly intervals during the summer) showed that never during the period of our studies was the density of either population so reduced as to be below the minimal. In general, the starfish population of Long Island Sound remained large, as attested by our surveys and also by the extensive and continuous efforts of the oyster growers combatting these pests. The oysters, although reduced in number because of poor sets during the past seven or eight years, and the heavy mortality caused by the storm of 1950, are still numerous enough to be counted by the hundred thousand bushels. For example, we know that on the beds of a single oyster farming company in the Bridgeport area, there are now approximately 150,000 bushels of two-year-old oysters. Considering the unusually high fecundity of the oyster and the comparatively high fecundity of the starfish we believe that there are still sufficiently large parent populations of both species to produce enough spawn so that, under favorable conditions for survival and growth of larvae, heavy sets could result. This was well demonstrated for starfish during the summer of 1952 (Fig. 1). Since we know this and since our other studies, to be reported elsewhere, have shown that there is no direct relationship between the numbers of spawners available and the intensity of setting of oysters or starfish in Long Island Sound, we may conclude that the fluctuations in parent populations were not the principal causes responsible for the lack of relationship observed between the intensity of setting of the two species during our 18-year studies.

Although at this time we lack data to demonstrate it, an absence of relationship in the intensity of setting of oyster and starfish larvae may be due to only one or to a few causes of rather specific nature. For example, there is little doubt that the larvae of the two species may exhibit different food requirements, as far

as size and quality of food organisms are concerned. Thorson (1946) says that an advanced echinoderm larva can take in particles as large as 50  $\mu$ , while our observations have shown that even "eyed" oyster larvae, about ready to metamorphose, require food of much smaller size, probably not over 15  $\mu$  in diameter. Moreover, since it has already been demonstrated that the larvae of even such closely related species as oysters and clams display widely different food requirements (Loosanoff, 1950; Davis, 1953), it is clear that even those food forms that are small enough to be taken in by both species may not be assimilated by one of them. Consequently, the presence or absence of such specific food organisms may be primarily responsible for the survival and, therefore, intensity of setting of larval oysters or starfish.

Another possibility to be considered is what we call, for lack of a better name, "water factor", which probably indicates the presence in sea water of certain dissolved substances that are needed for the normal existence and development of certain marine animals. These aspects of sea water chemistry and of animal behavior are still not well understood but we have evidence indicating that under laboratory conditions the presence or absence of this, at present, undetermined substance, or substances, may affect the growth of larvae of one species while not affecting the larvae of another closely related form (Davis, 1953).

Finally, only recently has the attention of biologists been called to diseases and parasites of lamellibranch larvae (Davis *et al.*, 1954; Loosanoff, 1954). It is possible, then, that larvae of other marine invertebrates, such as starfish, may also be victims of attack of different pathogenic micro-organisms, and that these micro-organisms may affect only closely related groups. If this is true, such organisms may sometimes eliminate the larval population of one species without harming the other. As a result, although most of the other conditions of the environment would be equally favorable to larvae of both forms, the larvae of the species suffering the epidemic would fail to set. Perhaps pathogens, together with specific food requirements of the larvae and the role of the water factor in their existence, explain in part the lack of relationship in the intensity of setting of oysters and starfish in Long Island Sound.

Since in the history of marine biology there are only a few studies when simultaneous systematic observations of the reproductive behavior of two ecologically closely associated species have been conducted steadily in the same area for long periods, we hope that the information offered in this article will contribute to a better understanding of the fluctuation in the natural populations of marine invertebrates existing in the same habitat.

We wish to extend our thanks to Barbara Myers for the statistical analysis of the data used in this article and to Rita Riccio for helping prepare the manuscript.

#### SUMMARY

1. No consistent relationship was found between the intensities of the oyster and starfish sets of Long Island Sound during the 18-year period, 1937-1954.
2. It is suggested that specific larval diseases, specific food requirements and presence or absence in the water of certain, at present, undetermined substances,

may be responsible, to a large extent, for the fluctuations in the intensity of setting of the two species in different years.

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